About the Presenter

Andrew Furlong
- Global Director Bauxite and Alumina, Worley
- B.E. (Chem), M.Sc. (Energy)
- 25+ years in the Alumina Industry
- Commenced in 1994 with Aughinish Alumina, Ireland
- Based in Brisbane, Australia
- Email: andrew.furlong@worley.com
Are we on the cusp of the Age of Aluminium?

- The Iron Age developed into the Steel Age that continues today.
- A sustainability focus demands lighter, more durable materials with strong recycling credentials.
- Will we see the Age of Aluminium?
- To progress, the industry must reduce its carbon footprint.
Energy Usage - Where have we come from?

Bayer Refineries – Process Energy Consumption

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1890</td>
<td>Batch operation, no heat recovery</td>
</tr>
<tr>
<td>1910</td>
<td>Single flash heat recovery stage</td>
</tr>
<tr>
<td>1935</td>
<td>Calcination kiln, rotary cooling</td>
</tr>
<tr>
<td>1950</td>
<td>Static Calciners, Plate Heat Exchangers</td>
</tr>
<tr>
<td>1960</td>
<td>Single Stream shell &amp; tube heating</td>
</tr>
<tr>
<td>1965</td>
<td>Single stream tube in tube heating</td>
</tr>
<tr>
<td>1971</td>
<td>Indirect Bauxite &amp; Precip Slurry HX</td>
</tr>
<tr>
<td>1980s</td>
<td>Double Digest, FF Evaporator, MR, Mix HT</td>
</tr>
<tr>
<td>2000s</td>
<td></td>
</tr>
</tbody>
</table>

30 GJ / t → 7-8 GJ / t

Sandy alumina yield Increase 50 to 100 g/L
Energy Usage – Where might we go?

- Energy usage will continue to decrease driven by:
  - Carbon social licence.
  - Pursuing competitive opex advantage.
- Energy reduction actualised by technology development – equipment & flowsheet.
- Chart demonstrates areas of opportunity.
- Energy efficiency will not take us to net zero emissions.
The Journey to Zero Carbon

Old technology. Coal fired boilers and grid electricity. HFO kilns. Low yield. 
~1.6 t CO$_2$e / t

~0.5 t CO$_2$e / t

The 2050 goal: 
Net 0 kg/t CO$_2$e

World average: 
~1.2 t CO$_2$ e / t Al$_2$O$_3$
Our response to the energy transition
A look at Alumina

Legend:
TRL  Technical readiness level
CO₂  Carbon dioxide
CHP  Combined heat and power
H₂   Hydrogen
WtE  Waste-to-energy
CST  Concentrated solar thermal
MVR  Mechanical vapour recompression
PV   Photovoltaic

Sectors:
- Upstream & Midstream
- Refining & Chemicals
- Mining, Minerals & Metals
- Power & Water

Fossil fuels:
- Coal/Oil
- Gas
- Concentrated solar thermal

Green energy:
- Solar PV/Wind/Nuclear/Electricity
- Blue H₂ blending
- Green H₂ blending
- H₂ storage
- Geothermal
- Electric boiler
- MVR
- CO₂ sequestration
- CO₂ residue sequestration
- WtE
- Solar gas
- Molten salt storage
- 2 Phase calciner
- CST calciner
- Optimised MVR
- Electric calciner
- Microwave calciner

Site green energy storage
Transient renewable advantage
Captive fossil fuel advantage
Thermal Energy Storage

- Renewables are variable. Refineries need reliable energy supply.
- Numerous energy storage solutions are emerging.
- Refineries have the advantage of needing heat energy, reducing conversion costs.
- There is money to be made in “firming” electrical networks.
- Creates value through firming, improved access to low-cost renewables.

Example:
- 2 Mtpa refinery
- 8 GJ/t total energy
- 4 GJ/t process energy
  - Equivalent 100% electricity ~500 MW
  - 12 hr process energy storage ~3 GWh
MVR is proven technology in multiple industries.
MVR not yet adopted in alumina
- No economic driver. Electricity vs coal/gas pricing
- Adaptation of technology required, notably flash steam quality in Bayer process.
MVR is more energy efficient – no loss of latent heat. ~0.5 to 1GJ/t saving for MVR Evaporators.
Drivers to push industry to adopt MVR
- Expected initially in evaporation and then more broadly.
What Could This Look Like?

**Solar PV / Wind / DES / Thermal Storage**
Green equity / government support
Network: firming value
Refinery: include thermal storage to firm decarbonised energy supply, take arbitrage advantage, replace/reduce live steam heating.
Region: accelerate renewables, economy of scale

**Hydrogen**
Initial user that underpins development of H₂ hub.
Offtake for blending into Calcination and/or CHP.
Calcination converted to fire on H₂ + O₂ removing CO₂, NOₓ, recovering water and providing O₂ sink.

**Electrification**
Electric Boilers
MVR Evaporation
Expanded application of MVR across Bayer Circuit

**CCS Co-generation**
Government funded Gas CHP to replace ageing coal-fired assets.
CHP efficiency synergy with export to smelter.
Long term refinery energy pricing with captive gas.
Utilise residue as CO₂ sink (neutralising / upgrading BR).
Synergies with local cement industry via residue as CO₂ sink and/or cement substitution.
Challenges Decarbonising Alumina

**Technology Must Be Developed**
Emerging competing technologies. Transfer from other industries. Technology maturation required. *Pick the right horse!*

**Complexity of Playing Field**
Many potential pathways. Path is site dependent. Interdependency with electricity networks. *Be wise, learn from others’ mistakes!*

**Significant Investment Required**
Optimisation of portfolio is critical. What are the cost and risk trajectories? Do right project then do project right. *Invest wisely!*

**Timing is Set**
Goals have been set. Momentum is shifting. *Don’t miss the boat!*
Broad Skillsets Required
You need a good navigator for the Energy Transition voyage

- **Strategy vision**
  - Government Advisory, Strategic Advisory, Decarbonisation Trajectory and Risks

- **Financial Analysis we can compare**
  - Estimating, Techno/economic analysis, Energy Network commercials

- **ET Technology Expertise we understand the options**
  - Power, Wind, Solar PV, CSP, Battery & Thermal Storage, MVR, H₂, CCS, DES…

- **Alumina Refinery Expertise we get you!**
  - Industry leading Alumina Specialists, familiar with your site

You need a good navigator for the Energy Transition voyage.
Worley’s Energy Transition Role

- Navigate the Roadmap with our customers
- Bring broad cross sector capability
- Develop and adapt technology
- Determine the right solutions to fit each customer
- Implement solutions
Worley delivering the Energy Transition

2360+ project experiences

<table>
<thead>
<tr>
<th>Solar power</th>
<th>Wind power</th>
<th>Geothermal, hydro and ocean power</th>
<th>Nuclear power</th>
<th>Renewable fuels and waste to energy</th>
<th>Hydrogen</th>
<th>Distributed energy and storage</th>
<th>Electrification and energy efficiency</th>
<th>Carbon capture and storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>336+</td>
<td>685+</td>
<td>286+</td>
<td>216+</td>
<td>139+</td>
<td>82+</td>
<td>218+</td>
<td>201+</td>
<td>205+</td>
</tr>
<tr>
<td>Solar power projects</td>
<td>Wind power projects</td>
<td>Geothermal, hydro and ocean power projects</td>
<td>Nuclear power projects</td>
<td>Renewable fuels and waste to energy projects</td>
<td>Hydrogen projects</td>
<td>Distributed energy and storage projects</td>
<td>Electrification and energy efficiency projects</td>
<td>Carbon capture and storage projects</td>
</tr>
</tbody>
</table>

- **950 MW**
  - World's largest CSP/PV hybrid project
- **310 MW**
  - Largest onshore wind farm (and largest in Africa)
- **20 GW**
  - Largest hydropower project
- **2600 MW**
  - Largest offshore wind farm
- **30+ GW**
  - Nuclear projects over 55+ years, in 40 countries across 4 continents
- **280,000+** barrels per day (4.29 billion gallons/year) of renewable fuels from 34+ projects
- **280,000+** barrels per day (4.29 billion gallons/year) of renewable fuels from 34+ projects
- **280,000+** barrels per day (4.29 billion gallons/year) of renewable fuels from 34+ projects
- **36 GW**
  - Largest green hydrogen electrolyser studied, combined with offshore wind
- **30 MW**
  - Largest battery energy storage project
- **$20m/yr**
  - Savings achieved through energy efficiency and electrification for a single industry client
- **100 MT**
  - CO₂ expected to be captured and stored on world’s largest CCS project

---

TMS2021 VIRTUAL • MARCH 15-18, 2021
www.tms.org/TMS2021 • #TMSAnnualMeeting
Conclusion

• The Energy Transition will be an incredible journey for the sector!
• The Age of Aluminium is in sight!
• We need to navigate a careful course.
• Some may fail along the way…
• ..but there are rewards for those who succeed in adopting the right pathways.
• All aboard! It’s time to set sail!